LCAs for Waste

Life Cycle Assessments for Waste, Part III:

The Case of Paint Packaging Separation and General Conclusions

Strategic EIA for the Dutch National Hazardous Waste Management Plan 1997-2007

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Preamble

This series of three articles titled "LCAs for Waste" describes the experience of performing comparative assertions of hazardous waste management technologies for the second Dutch National Hazardous Waste Management Plan (NHWMP) 1997-2007. For this plan, Dutch legislation required that a strategic (thus: chain-oriented) Environmental Impact Assessment (EIA) had to be made. The NHWMP, which was written in parallel, used the EIA's results directly to establish so-called 'minimum standards'.

These can best be described as a 'Best available technology' for management of certain hazardous wastes. Only such technologies would be licensed under the NHWMP.

The **first part** describes the Dutch hazardous waste management structure, and the goal and scope definition step for the chain-oriented EIA.

The **second part** presents a comparison of thermal treatment technologies.

The **third part** provides a comparison of paint packaging separation plants. Furthermore, it gives a general review of the usefulness of LCA for the NWHMP, its acceptance in the public consultation phase, and the experience with the review process by the Dutch EIA commission.

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Abstract. This is the final paper of a series of three on the use of LCA in a strategic EIA made for the second Dutch National Hazardous Waste Management Plan (NHWMP). A comparison of two options for paint packaging waste separation is given: cryogenic versus shredder-flush separation. The high liquid nitrogen use in the cryogenic process, and particularly the energy needed to produce it, tends to make the cryogenic process environmentally less favourable. As for the other technology comparisons in the EIA, no particular problems arose. The EIA passed its peer review successfully and survived a very extensive public review procedure, in spite of the fact that it supported decisions involving very high financial stakes. Several lessons can be learned from this experience. First, LCA is a suitable tool in strategic EIAs on waste. Second, time-consuming, interactive public participation in LCA is no precondition for public acceptance – a process of *stakeholder deliberation* that ensures that the practitioner knows the relevant perspective is enough. Third, high decision stakes do not automatically demand very extensive LCA work. Our experience shows that LCAs just above screening level can provide robust support to decisions involving dozens of million Euros. More extensive work would not have lead to more specified preferences. Rather, in our view, being well aware of the key discussion points in advance which are seen as relevant for the comparison by stakeholders, and having good insight in the related inherent limits of LCA, is the key to optimal decision support with LCA.

Keywords: Dutch National Hazardous Waste Management Plan; EIA; Environmental Impact Assessment (EIA); hazardous waste; LCA; Life Cycle Assessment; paint waste; separation of paint and packaging; waste management

1 Introduction

This paper discusses the use of Life Cycle Assessment (LCA) in the context of a strategic Environmental Impact Assessment (EIA) made for the second Dutch National Hazardous Waste Management Plan (NHWMP). As a second case, we analyse the selection of the best technology ('minimum standard') for the separation of paint and paint packaging (Section 2), and the bottlenecks in the other eight comparisons for which we used LCA on a generic level (Section 3). In Section 4, we end with overall conclusions about the use, results and acceptance of LCA in this tense and complicated decision support process.

2 A Comparison of Separation Technologies for Paint Waste

2.1 Historical context

By 1990, an enforcement programme and the realisation of a collection system for small hazardous waste flows had lead to such high waste supplies that Dutch rotary kiln capacity became fully insufficient. Particular problematic became incinerable hazardous waste in packaging, since only rotary kilns can handle this waste (see Part II: Int. J. LCA 4 (6) 341-351 (1999)).

The packed hazardous waste mainly originated from the collection system of small quantity hazardous waste. This system ran into a real crisis, since it was no option to stop the collection from households and SMEs who just had been haunted with public awareness and waste law enforcement campaigns. A temporary measure taken, i.e. allowing the

export of paint waste to the Schoneberg landfill in Eastern Germany, was equally embarrassing. Newspapers started to publish that the hazardous waste so meticulously kept apart by the average citizen was dumped after all. A temporary storage was built to provide initial relief.

The majority of this waste appeared to be paint packaging. Two companies proposed technologies to separate hazardous paint residue and the packaging. The latter forms 50% in mass and consists mainly of tinned steel, available for re-use after separation. The paint fraction would come available as a much easier to incinerate sludge or solid bulk stream. One company proposed separation with spent solvents, and the other cryogenic separation with liquid nitrogen[1]. At the time, the pressure was so high that no one bothered to make a chain-oriented comparison. Both firms were granted a license. In their project EIAs, the firms only had to address how to prevent local environmental problems[2]. Once the technologies proved successful, other firms also started to apply for licenses. In this context, the authorities had to answer the question as to which technology is indicated as being preferable in the NHWMP 1997-2007.

2.2 Choice of the functional unit, relevant technologies, and data inventory

2.2.1 Functional unit and relevant technologies

In the comparison, the choice of the functional unit is straightforward: the treatment of 1 tonne of average paint packaging waste (some 50% sludge, 37.5% tinned metal, and 12.5% plastic (VROM, 1993; Smeets and Tukker, 1995)). As indicated, the relevant technologies are, separation with solvents and cryogenic separation. The systems related to these technologies, and the related data inventory, are discussed below. Interventions related to background or avoided processes like electricity generation for the Dutch grid were taken from generic databases (e.g. AOO, 1995). Treatment of residues is irrelevant in the comparison, since they are the same for both processes.

2.2.2 Cryogenic separation: System boundaries and data inventory

The cryogenic process exists in a few modifications, but basically consists of the following steps. Paint packaging waste is shredded and subsequently passed through a bath of liquid nitrogen (-196°C). This cools the materials and makes the paint fraction brittle. Due to differences in extension coefficients, the paint becomes brittle and attaches less tightly to the packaging. A hammer mill subsequently provides separation of waste paint, metal and plastic. The plastic is usually incinerated as a non-hazardous waste; the metal goes to the scrap circuit, and the waste paint has to be incinerated in a rotary kiln[3].

There are no emissions to water. A regenerative oxidation unit (REOX) treats the VOC emissions. Final emissions to air and direct electricity use were calculated on the basis of a project-EIA for the cryogenic plant of Hoogers (1995). Usually a use of about 1 tonne of liquid nitrogen per tonne of waste is noted (ATF, 1993; Hoogers, 1995; InterChem, 1994), However, after the draft LCA was published, one company claimed that 500 kg per tonne of paint waste was feasible (Leto, 1996)[4]. The nitrogen is co-produced with oxygen and other trace gases by cooling air, which, in turn, requires electricity: 3.6 MJ per kg according to Hoogers (1995) or 2 MJ per kg according to Frischknecht (1994). This different data on nitrogen uses and electricity needs have been applied in a sensitivity analysis. The system at stake is visualised in Fig. 2.1, the data inventory in Table 2.1.

2.2.3 Separation by a shredding-flush process: System boundaries and data inventory

The shredding-flush process separates and cleans paint packaging using several other waste flows that normally would directly be sent to incineration. In an inert atmosphere, the material is shredded. The shredded fraction is subsequently stripped with paint sludge, organic materials and water. The waste flows from the strippers are sent into a recirculation process, resulting in a water and solvent fraction which is again used for stripping, and in a stable emulsion usually incinerated in a rotary kiln. The clean metal fraction can be used in the scrap circuit. The plastic fraction is incinerated as normal waste. The process was claimed to be waste-water free.

VOC-containing air flows generated in the firm are treated by a REOX. The project-EIA of the firm allowed for a calculation of the emissions to air and electricity use that had to be allocated to the shredder-flush unit (ATM, 1993)[5]. The installation treats 18,000 tpa paint packaging waste and 15,000 tpa paint sludge. Pre-treatment of the latter flow also results in an easier input into a rotary kiln. Hence, the pretreatment process was relevant for 33,000 tpa packaging and sludge combined[6]. No other primary materials were

[1] Both technologies faced initial technical setbacks. Explosion dangers are a common problem with shredding processes in general. The shredder-flush process needed quite some trial-and-error before clean metal and pumpeable sludge was obtained from the process, but eventually ran smoothly.

[2] Concerning technology selection, firms simply tended to mention a negative aspect of its competitor to justify their own choice: the energy use in cryogenic separation and the emissions of Volatile Organic Carbon (VOC) in the shredder-flush process separation (e.g. ATM, 1993; Hoogers, 1995).

[3] The waste paint usually contains too many heavy metals to be accepted in a MSWI. For this reason, incineration in cement kilns is also questionable (see **Part II**, Table 3.3 and Section 3.3.3: Int. J. LCA 4 (6) 341-351 (1999)).

[4] In a very recent follow-up project detailed investigations showed that this firm uses about 650 kg nitrogen per tonne of waste (Tukker and Simons, forthcoming).

[5] The nitrogen needed for inertisation is minimal compared to the cryogenic process, produced on site, and hence included in the aforementioned electric energy use

[6] Furthermore, there is an input of 5,000 tonnes organic material, which normally is incinerated in a rotary kiln. Some 2,000 tonnes are oily residues from the firm's waste water treatment plant for ship's waste, and some 2,000 tonnes are non-distillable materials supplied by AVR and collectors of small hazardous waste quantities. In sum, the organic material simply takes a detour via the paint separation plant to its usual destination, the rotary kiln, and thus was kept out of the comparison. Competitors argued that the organic flows would be suitable for distillation and re-use as a solvent. This seemed unlikely given their origin, but we included a sensitivity analysis in which we took the differences in environmental impacts related to distillation and incineration in a rotary kiln into account. We refrain from giving the analysis here, since then we would have to discuss the case of distillation as well. Only in the unlikely event that all 5,000 tonnes would be distillable to a secondary solvent, the superiority of the shredder-flush process became uncertain.

needed. The water in solvent-lean paint was enough to provide the water needed in the flushing process. The system is visualised in **Fig. 2.2**, the data inventory in **Table 2.1**[7].

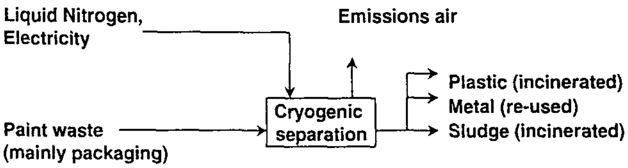

Fig. 2.1: The system related to cryogenic separation (grey: not included or relevant in the comparison)

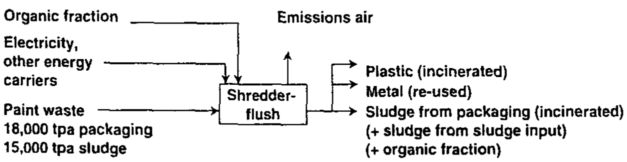

Fig. 2.2: The system related to shredder-flush separation (grey: not included or relevant in the comparison)

Table 2.1: Inventory table for the paint separation processes (in tonnes per tonne waste, unless otherwise specified)

PROCESS	Cryogenic	Shredder-flush
Emissions to air		
Dust	1.50E-05	
Cl (HCl)	2.27E-06	6.70E-06
SO_2	a)	1.98E-05
NO_x	7.94^{E}-05	3.33E-05
CO_2	a)	1.00E-02
CO	a)	6.06E-06
C_xH_y	3.90E-04	3.03E-04
Benzene		4.24E-07
Acrylates		6.06E-09
Economic input		
Electricity (MJ)	2.25E+02	3.18E+02
Gas (MJ)		1.91E+01
Oil (MJ)		9.09E+01
N_2 (tonne)	1.00E+00 or 0.50E+00	
Economic output		
Plastic	1.25E-01	1.25E-01
Tinned steel	3.75E-01	3.75E-01
Paint sludge	5.00E-01	5.00E-01

a) It is likely that emission abatement with a REOX of the cryogenic plant will also produce these emissions. However, they were not included in our data sources. If they are equal to the emissions from the shredder-flush process, the emissions from the REOX contribute to the total theme score for the cryogenic process to only a few percent.

2.3 Impact assessment

For the impact assessment methodology, we refer to Part I. In brief, it concerned:

- The 1992 CML guide was used (HEIJUNGS et al., 1992), making some minor adaptations like including primary energy use and final waste as impact categories;
- Normalisation took place on the basis of Dutch total scores for 1990;
- Weighed scores were calculated with 3 methods: Distance to Target (DtT) related to Dutch policy goals for 2000, DtT without final waste, and all themes equal waste.

The results are given in **Table 2.2** and **Fig. 2.3** (*s. p. 108*), and suggest that the shredding-flush process has advantages on virtually all environmental themes. The underlying data, not presented here due to space constraints, shows that the whole comparison, except for smog formation, is dominated by interventions related to the generation of electricity. Hence, the electricity needed to produce the liquid nitrogen for the cryogenic process is decisive in the comparison. Otherwise, the technologies can only start to score equal if a truly worst-case assumption is applied to the shredder-flush process: i.e. that all interventions have to be related to the 18,000 tpa paint packaging only, and not to the 33,000 tpa waste treated in total. Even then the best-case assumptions for the cryogenic process are still needed (low nitrogen use, low electrical energy use in liquid nitrogen production).

2.4 Discussion and conclusion

The results of this LCA generated a fierce discussion. Several firms had only recently invested in the cryogenic technology and relied on it for a large part of their turnover. Since they could not challenge our minimum use of 500 kg nitrogen per tonne of waste, they mainly scrutinized our calculation of the energy use per kg of liquid nitrogen.

Some firms objected that they would start to buy their nitrogen in France – there, electricity is generated with nuclear power leading to much lower emissions. Furthermore, the ETH-data we used presumably allocated the electricity used for cooling air on a mass basis to the amounts of nitrogen and oxygen produced (FRISCHKNECHT, 1994). One firm argued that no impacts should be allocated to nitrogen at all. They bought it from a plant producing liquid oxygen used in a blast furnace, and argued that the liquid nitrogen was a waste to which no electricity use should be allocated[8].

These arguments are clearly too extreme. For commodities such, as liquid nitrogen, it seems most logical to assume that

[7] After the EIA was completed, the firm made important process changes that probably worsened the environmental performance of the treatment route. They started to pyrolyse their sludge and the plastic fraction on-site, and our most recent investigations suggest that the energy recovery from this pyrolysis may be lower than from incineration. Furthermore, they started to use high volumes of non-recirculated water for metal cleaning, leading to emissions to water. On top of that, very recently the firm decided to treat paint waste directly in the pyrolysis since they found a way to recover the metal from this process, and to decommission the shredder flush process (TUKKER and SIMONS, forthcoming).

[8] One firm even commissioned its own peer review. Unfortunately, the practitioner at stake made a slip of the eye when reading inventory tables. In order to have low effects for electricity consumption, they assumed a combined heat-power generation with gas. To keep results comparable with the EIA on the NHWMP, they wanted to use the EIA's inventory tables. They appeared to have not used the inventory data from column 'heat generation by combustion of gas', but from the column 'extraction of gas' when they calculated the interventions from the heat-power generation plant.... This review was quoted in a newspaper published by the firm, but it is needless to say that the argument was not taken over by the authorities or in the formal peer-review process by the EIA Commission.

Table 2.2: Normalised theme scores for the separation of 1 tonne paint packaging

Theme and DtT Factor	Humtox	Ecotox.	GWP	ODP	POCP	Acidif.	Eutrophic.	Volume	Energy	Weighted scores		
Technology	1,7	1,7	1,2	35,3	2,3	2,6	2,8	3,1	1,02	All equal	DtT	DtT ex vol.
Cryogenic (0,5 ton N2, 2 MJ/kg); BEST CASE	1,16E-09	0,00E+00	9,97E-10	0	2,76E-09	6,64E-10	6,77E-11	1,81E-09	1,12E-09	8,58E-09	1,82E-08	1,26E-08
Cryogenic (1 ton N2, 3.6 MJ/kg)	2,40E-09	0,00E+00	3,11E-09	0	3,14E-09	1,95E-09	1,89E-10	5,65E-09	3,50E-09	1,99E-08	4,17E-08	2,42E-08
Shredder-flush (33,000 tpa)	6,24E-10	2,07E-12	3,04E-10	0	2,08E-09	2,19E-10	1,99E-11	4,70E-10	3,34E-10	4,05E-09	8,64E-09	7,18E-09
Shredder-flush (18,000 tpa); WORST CASE	1,14E-09	3,80E-12	5,57E-10	0	3,82E-09	4,01E-10	3,66E-11	8,62E-10	6,12E-10	7,43E-09	1,90E-08	1,63E-08

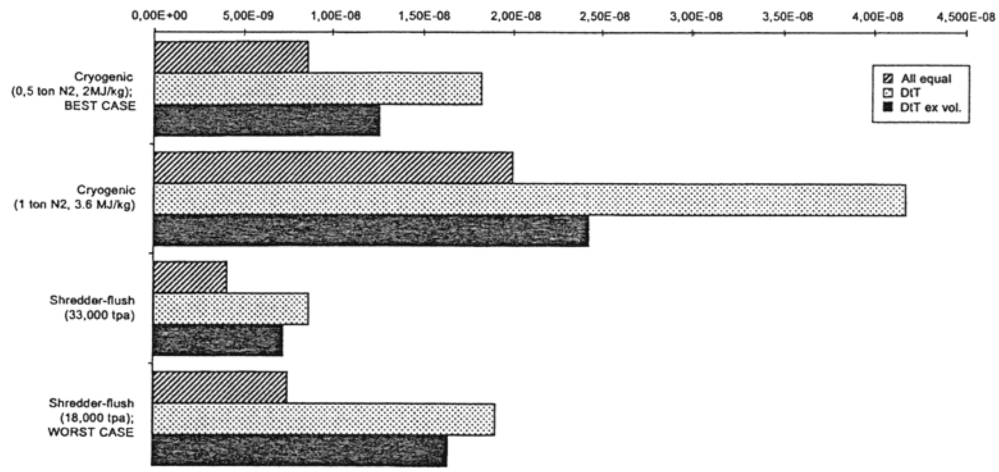

Fig. 2.3: Comparison of weighted theme scores for the separation of 1 tonne paint packaging

there is a European market, suggesting that it is best to use electricity data for the average European grid, which differ hardly from the Dutch grid (which we used). The waste argument is unrealistic since nitrogen has a clear market value.

Thus, with some caution, the cryogenic process can be indicated as the less desirable one[9]. For final conclusions, practical test data about the nitrogen use in the cryogenic process is required. Furthermore, a more elaborate sensitivity analysis on the allocation of electricity use for nitrogen is desirable. This could include an assessment to what extent the markets of liquid nitrogen and oxygen are in balance with the stochastic output of the cooling process.

3 Further Experiences with the LCAs for the NHWMP

3.1 Experience with LCA in other sectors

Table 3.1 summarises what comparisons were at stake in the other sectors of the EIA for the NHWMP (Tukker et al., 1996). In these other sectors, the performance of the LCAs, in general, generated no other problems compared to those highlighted in the cases discussed to date.

The most interesting point occurred in sectors 2 (solvent treatment) and 4 (treatment of the oil fraction of oily sludges), particularly in the comparison of solvent c.q. oil recycling with incineration in a coal power plant. Like in Part II, system enlargement was preferred to deal with (or better: to avoid) allocation. Thus, when the oil or solvent is recycled in its own substance chain (option a), the power plant runs fully on coal. When the oil or solvent waste is used as a fuel in the electricity plant (option b, cascading), the power plant does need less coal. However, a primary resource (mainly oil) is now needed to produce the virgin solvent or oil. The overall comparison appeared to be in favour of cascading (b), not least of all since coal usually contains more problematic components with regard to the energy plant like metals and sulphur than waste oil or spent solvents. However, there is an interesting peculiarity at stake. Cascading (b) simply implies that the societal (sub)system we analysed is covering its energy and feedstock need mainly with oil, where in the recycling option (a) it is covered by a mixture of oil and coal (→ *Fig. 3.1* and *3.2*). In sum, the environmental gains are in its essence simply related to a switch to a cleaner energy carrier. At the same time, however, it is clear that this gain is questionable. Coal is less scarce than the relatively clean oil. It is probably still hardly possible to deal objectively with this difference in scarcity, and we did not include it as an indicator in our analysis. However, it is obviously a key point in the comparison.

3.2 Peer review

The EIA was accepted by the expert committee of the EIA commission, but not after a fierce discussion as to why we did not want to include the terrestrial ecotoxicity or the leaching of metals from the final trajectory of waste man-

[9] In view of note 7, however, we are quite uncertain if this clear conclusion still applies in the current situation.

Table 3.1: Comparisons in other sectors

Sector No.	Comparison		Approach
2: Oil/water/sludges	a.	treatment of the oil fraction * rotary kiln * combi-kiln * cement kiln * coal power plant * processing to secondary fuel	LCA
	b.	treatment of the sludge fraction * rotary kiln * combi-kiln * cement kiln * thermic soil cleaning unit * MSWI	LCA
	c.	treatment of drilling oil * rotary kiln * combi-kiln * cement kiln * oil/water separation plus input oil fraction in blast furnace * oil/water separation plus input oil fraction in cement kiln	LCA
3: Photochemical waste (PCW)	a.	treatment of paper and film * MSWI * Shredding and landfill * Shredding and PET-recycling * Fuel for pyrolysis of liquid PCW	matrix LCA
	b.	treatment of photochemicals * biochemical treatment * osmosis, vaporisation, immobilis. * pyrolysis and inertisation	matrix LCA
8: Spent packaging for chemical substances (SPC)	a.	treatment of paint sludge * rotary kiln * combi-kiln * cement kiln	LCA
	b.	separation of paint and packaging *shredder-flush process *cryogenic process	LCA
	c.	treatment of plastic packaging with paint * direct incineration in a rotary kiln * direct incineration in a MSWI * separation (shredder flush), plastic to VEBA process, sludge to rot.kiln * separation (shredder-flush), plastic to MSWI, sludge to rotary kiln	LCA
9: Solvents	a.	treatment of halogen-free solvents * rotary kiln * combi-kiln * cement kiln * coal power plant * distillation	LCA
19: Car oil filters	a.	treatment of oil filter * shredding, incineration in MSWI * shredding-flush separation, re-use tin fractions	LCA

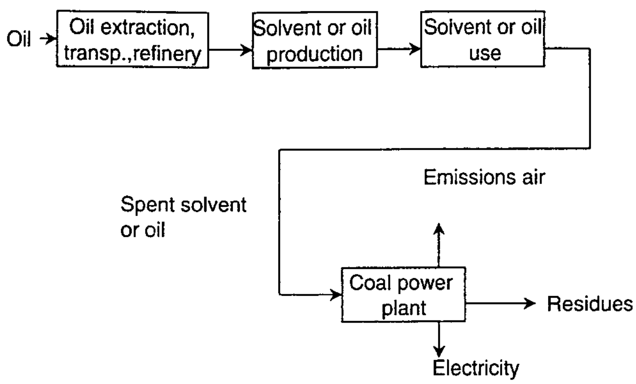

Fig. 3.1: Cascading of waste solvent or waste oil

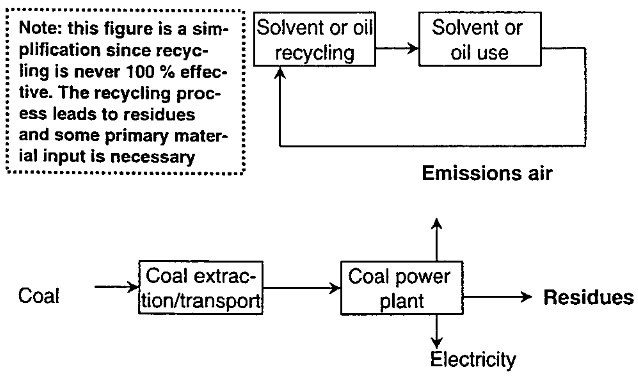

Fig. 3.2: Recycling of waste solvent or waste oil

agement (EIA Commission, 1996; see also Section 3.3.3 in Part II). In the end, the EIA commission acknowledged that this was a knowledge gap and that no preference could be spoken out, so that calculations would have easily a 'garbage in, garbage out' character[10].

Oddly enough, the EIA commission didn't ask any question on the waste streams that we had evaluated with a qualitative +/- approach. Exactly this approach had been used to evaluate the waste management options like landfill and immobilisation of highly leachable waste that contains much more metals than any incinerable waste – which was evaluated with LCA and thoroughly questioned on the 'heavy metal knowledge gap'. A clear example that intransparent methods like expert judgement protect themselves against difficult questions, where LCA is easily attacked due to its quantification and transparency.

Finally, the EIA commission made some remarks that may give the LCA community some thinking. They indicated that LCA, *at its current state of the art*, should be used very cautiously. Specifically the limited ability of LCA to deal with toxicity concerned them[11] – after all, hazardous waste management mainly aims to reduce toxicity burdens. In this respect, the EIA commission backed the choice of the practitioner to be very careful in speaking out preferences, despite the initial wish of the authorities to do so.

3.3 Public participation and acceptance

During the process of writing the EIA, stakeholders were not given a formal role. Instead, we tried to ensure to include important views by a process of stakeholder deliberation[12]. Stakeholder views were analysed beforehand, e.g. via literature analysis, telephone interviews or informal meetings with stakeholders on critical subjects. When potentially controversial results were produced, we checked informally which argument the affected party would have against it. Then, on our own, we wrote final conclusions making use of any problem framing that had in our view enough quality to be taken into account (cf. Tukker, 1999). In this way, the strategic behaviour and delays that often occur during participatory processes were avoided.

Once the EIA and draft NHWMP were ready, a formal public rehearsal procedure started. The result was an avalanche of some 120 reactions of firms in the hazardous waste management structure, public authorities, environmental groups, and individuals, totalling some 600 pages (see for a summary: VROM/IPO, 1997a). Comments were sometimes heavy. After all, it was the first time that LCAs structurally had been performed for the Dutch hazardous waste management system. It is thus hardly surprising that several existing, intuitive ideas about which technologies were environmentally preferable proved to be untrue. This could result in hard lessons for companies who had invested in technologies without insight in their environmental performance on system level. One can imagine, for instance, that the Dutch firms owning rotary kilns and cryogenic paint separation plants were not amused about the conclusions of the EIA (see Part 2 and Section 2).

In general, neither these comments nor more extended research fundamentally affected the conclusions of the EIA. The main defence against this was the rather general conclusions we tended to draw. We rejected technologies only if they scored structurally very bad, and, maybe most important, if we could find a very logical reason why. In all other cases, we refused to speak out clear preferences. In the end, displeased reactions were therefore mainly part of a process of accommodation to new realities.

This experience suggests that complicated, time-consuming interactive public participation during the execution of an LCA may not be a necessary precondition for acceptance - even when the stakes are high. The approach of stakeholder deliberation used here may well be a viable alternative.

3.4 Use of the results by the authorities

The national and provincial authorities were, in contrary to other stakeholders, very involved in the process of making the EIA. They had to, since parallel to the EIA they

[10] However, as indicated in Section 3.3.3 of Part 2, this discussion inspired us to try to give at least some guidance for what waste types this knowledge gap would start to dominate in our comparisons.

[11] It is noteworthy that, at the time of this review, we simultaneously experienced the problems with toxicity assessment in the Swedish PVC chain study (Tukker, 1998).

[12] I am indebted to Prof. Roland Clift who suggested this term for this approach during the CHAINET meeting in Sevilla, Spain, March 1999

themselves were involved in formulating their policy for about 20 waste sectors which were discerned in the plan. Of course, some results of the LCAs in our EIA were surprising for the authorities too. Luckily enough, they tended to adapt themselves to such new insights, rather than trying to neglect messages or to persuade us to reformulate conclusions. In most cases, policy proposals were well in line with the conclusions of the EIA (VROM/IPO, 1997b)[13].

One recommendation was not followed. We had stressed that cement kilns could only be regarded as an alternative in hazardous waste incineration, if extensive trial burns had shown no additional formation of particles of incomplete combustion (PICs; see Part II, Section 3.3.2). The precautionary principle suggests that when the potential damage related to uncertain risks is high, and prevention costs are low, an activity can only be allowed if an absence of danger is proven (cf. UNCED, 1992). The production of additional PICs such as dioxins can be seen as such a potential threat. A monitoring programme that costs a fraction of the financial gains of cement kiln operators when they treat hazardous waste can rule out this uncertainty in full. However, under the EU Directive of the Transboundary movement of waste, no export control was allowed any longer for the waste for recovery. The Dutch authorities found it inappropriate to check themselves if a foreign authority had executed enough precaution in the form of trial burns and monitoring when allowing cement kilns to recover/incinerate waste. The experience of 1998 shows that large amounts of waste that were formerly incinerated in rotary kilns are now exported to cement kilns.

4 Overall Conclusions

In three articles, we have shown the experiences with the applications of LCAs in a strategic EIA for the Dutch NHWMP 1997-2007. The EIA at stake mainly involved a location-independent comparison of the environmental performance of waste management alternatives. LCA appeared to be a suitable tool to be used in such an EIA on plan level. This experience is in line with other authors who used LCA in strategic waste management decisions (e.g. White et al., 1995; Finnveden and Huppes, 1995; Nielsen et al., 1998a and 1998b; Bez et al., 1998; Kremer et al., 1998).

The LCAs performed proved to be able to overrule a number of intuitive common sense ideas about good hazardous waste management practices, and, in several sectors, led to new insights about environmental improvements in hazardous waste management. For the authorities, it proved to be a tool on which they could base rather robust decisions that were founded on a rather transparent evaluation. Acceptance of the results was relatively good, and until now, no conclusions in the EIA have effectively been challenged. This was possible in a rather cost-effective and quick way. The final draft of the EIA was completed in some 7.5 months, and an input of some weeks research time was sufficient for most LCAs.

All this was in part due to the fact that most of the waste management chains at stake were relatively short and simple. Yet, we feel another key element was to have no exaggerated expectations of the discriminative power of the tool. In all cases, we deliberately set out to make an initial, screening-like LCA as quickly as possible. Time-consuming and complicating public participation processes were rejected, despite the tension and stakes related to the project. Ensuring that the practitioner *knew* all relevant stakeholder views, and could critically evaluate the results of LCAs from these perspectives, proved to be sufficient. Knowledge of these perspectives and the results of the screening-like LCAs were often sufficient to delete the worst scoring technology, or to indicate where additional data inventory would really have added value. In this stage it also frequently became clear that the further technology selection process would be totally or partially frustrated by a number of fundamental, practically unsolvable problems relevant in the discussion between stakeholders. Examples are the discussions about the best allocation method, the final fate of heavy metals, and the problems related to the possible creation of PICs which are decisive for the choice between a rotary kiln and a cement kiln. These discussions are unsolvable within the context of LCA. In such cases, one does not need a year-long, in-depth, data inventory process to tell the decision maker what the crucial elements are that have to be taken into account.

The consequence of our approach was that in most cases we ended up with a set of 2-3 'best' technologies between which no preference could be spoken out. Yet, I feel this is not a true problem. It simply reflects a reality that is often present in environmental decision making. I feel that in the case of complex environmental decision making problems, a fully objective scientific choice is more often than not unattainable. Complexity implies that choices have to be made more than once that cannot be based on science. Providing the decision maker with a ballpark insight about the pros and cons of his choice with cost-effective, rough and quickly performed LCAs is good enough, I feel that this case results in the following suggestions of how to use LCA for cost-effective decision support:

1. Ensure awareness of stakeholder views on the decision making problem. However, use an approach of *stakeholder deliberation* rather than a complicated process of public participation if the latter is not obligatory;
2. try to be well aware and accept the inherent limits of LCA, e.g. with regard to solving allocation problems and analysing toxicity problems;
3. apply a step-wise approach in the analysis, and simply dare to give relatively broad, ballpark advice based on rough calculations if points 1) and 2) make clear that a further refinement of the LCA cannot lead to a more specified preference among the alternatives in a truly objective way. The experience in this case indicates that this point may be reached sooner than is sometimes thought.

[13] Obviously, the authorities had to balance the environmental information with other elements. For instance, they decided not to withdraw the licenses for the cryogenic paint packaging plants in the NHWMP, since most firms had these plants only a few years. They announced that in the next NHWMP of 2001 these permits would be withdrawn, unless new information or new technical improvements would indicate that the environmental performance of the cryogenic installation was highly improved. This allowed the existing firms either to improve their installations, or adapt themselves gradually to a situation in which the cryogenic installations would not be used anymore.

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LCAs for Waste

Part I: Int. J. LCA 4 (5) 275-281 (1999)

Abstract. Part I (from three parts) of the series "LCAs for Waste" describes the Dutch hazardous waste management structure, and the goal and scope definition step for a chain-oriented Environmental Impact Assessment (EIA). For about 7 waste sectors, no change in existing policy was foreseen and Dutch legislation required no comparative assertion. For 7 others, a lack of inventory data or methodological problems did not allow for the performance of a meaningful quantitative LCA.

For the remaining 7 sectors, LCAs were performed to deal with 12 technology choices. They were based on primary data for the central processes, and literature data for background processes. A slightly adapted approach of the 1992 CML manual was used. System enlargement appeared to be slightly preferable as an allocation method.

Part II: Int. J. LCA 4 (6) 341-351 (1999)

Abstract. This paper (the second in a series of three) compares incineration options for hazardous waste with LCA. Provided that acceptance criteria are met with regard to metals, PAHs and chlorine, Dutch Municipal Solid Waste Incinerators (MSWIs) appeared to be preferable above rotary kilns since they have a better energy recovery and – unlike rotary kilns – produce re-usable slags. The position of the cement kiln relative to the MSWI and rotary kiln depends on the allocation method chosen. System enlargement, which may be most highly defensible, tends to give cement kilns the advantage. Yet, two key concerns which are unsolvable by LCA make final conclusions impossible. First, an input of highly contaminated waste leads to an enrichment of cement with metals. Long-term consequences are not known, so the incineration of waste with a high metal content will inevitably be controversial. Second, no convincing proof was found that cement kilns would not produce additional hazardous process emissions (e.g. dioxins) when using waste instead of fuel. The precautionary principle demands that such proof be provided before cement kilns can be considered for the incineration of waste with a composition other than their regular fuel.